Chapter 20: Measurement of Evapotranspiration

Introduction

Evapotranspiration is the combined process of evaporation from soil and water surfaces and transpiration from plants. It is a critical component of the hydrologic cycle, influencing the availability of water for irrigation, urban supply, reservoir design, and overall water resource management. Accurate estimation of evapotranspiration is essential for understanding water balance, drought assessment, and planning of irrigation systems. Various direct and indirect methods are used to measure evapotranspiration, ranging from empirical equations to sophisticated field instruments.

20.1 Evapotranspiration – Basic Concepts

- **Evaporation**: The process of water converting into vapor from open surfaces like rivers, lakes, and soil.
- **Transpiration**: The process through which water is absorbed by plant roots, moves through plants, and is lost as vapor through stomata in leaves.
- **Evapotranspiration (ET)**: The total water loss from both evaporation and transpiration.
- **Potential Evapotranspiration (PET)**: The amount of evapotranspiration that would occur with unlimited water supply.
- **Actual Evapotranspiration (AET)**: The actual water loss, which may be less than PET due to limited water availability.

20.2 Factors Affecting Evapotranspiration

Several climatic, plant-related, and soil factors influence evapotranspiration:

- **Solar radiation**
- **Air temperature**
- **Humidity**
- **Wind speed**
- **Soil moisture content**
- **Crop type and stage of growth**

- **Plant density**
- **Management practices (mulching, irrigation, etc.)**

20.3 Methods of Measurement of Evapotranspiration

Evapotranspiration can be measured or estimated using:

20.3.1 Direct Methods

These methods involve actual field measurements of ET.

a) Lysimeter Method

- A lysimeter is a tank embedded in the ground filled with soil and crops identical to the surrounding field.
- Measures change in weight due to water loss.
- Water inputs (rainfall, irrigation) and outputs (drainage, ET) are carefully monitored.
- **Advantages**: High accuracy.
- **Disadvantages**: Expensive, labor-intensive, not suitable for large areas.

b) Field Experimental Plots

- Known quantity of water is applied.
- Change in soil moisture and plant growth is observed.
- ET is calculated as a water balance.
- Used mostly for calibration of models.

20.3.2 Indirect Methods

These methods estimate ET using meteorological and empirical data.

a) Water Balance Method

- Based on the continuity equation:

$$ET = P - R - D - \Delta S$$

  Where:

  - P = Precipitation
  - R = Runoff
  - D = Deep percolation
  - ΔS = Change in soil water storage

- Effective for basin-scale studies.

b) Energy Balance Method

- Based on conservation of energy:

$$R_n = G + H + LE$$

Where:

  - R_n = Net radiation
  - G = Soil heat flux
  - H = Sensible heat flux
  - LE = Latent heat flux (related to ET)

c) Aerodynamic Method

- Uses principles of mass transfer.
- Based on wind speed and vapor pressure difference:

$$ET = C \cdot u \cdot (e_s - e_a)$$

Where:

  - u = wind speed
  - $e_s - e_a$ = vapor pressure deficit
  - C = empirical constant

d) Combination Method (Penman Equation)

- Combines energy balance and aerodynamic methods.
- Penman equation:

$$ET_0 = \frac{\Delta(R_n - G) + \gamma \cdot f(u)(e_s - e_a)}{\Delta + \gamma}$$

Where:

  - Δ = Slope of vapor pressure curve
  - γ = Psychrometric constant
  - $f(u)$ = Wind function

20.4 Empirical Methods

When direct data is unavailable, empirical equations are used for estimation:

20.4.1 Blaney-Criddle Method

$$ET = k \cdot p \cdot (0.46T + 8)$$

- k = crop coefficient
- p = monthly % of annual daylight hours
- T = mean monthly temperature
- Simple and suitable for planning purposes.

20.4.2 Thornthwaite Method

- Based on air temperature and day length.
- Monthly PET:

$$PET = 1.6\left(\frac{10T}{I}\right)^a$$

Where:

- T = mean monthly temperature in °C
- I = annual heat index
- a = empirical exponent

20.4.3 Hargreaves Method

- Simpler than Penman but more accurate than Thornthwaite:

$$ET = 0.0023 \cdot (T_{avg} + 17.8) \cdot ¿$$

Where:

- T_{avg}, T_{max}, T_{min} = average, max, and min temperature
- Ra = extraterrestrial radiation

20.5 Measurement of Pan Evaporation

Evaporation pans are widely used to estimate reference ET:

Class A Evaporation Pan

- Circular pan, 120.7 cm diameter, 25 cm depth.
- Water is filled and level is observed daily.
- ET is calculated using a pan coefficient:

$$ET_0 = K_p \cdot E_p$$

Where:

- K_p = pan coefficient (0.6–0.8)
- E_p = pan evaporation

20.6 Remote Sensing and ET Estimation

- Satellite-based sensors can estimate ET using surface temperature, vegetation index (NDVI), and albedo.
- Models like SEBAL (Surface Energy Balance Algorithm for Land) and METRIC (Mapping EvapoTranspiration at high Resolution with Internalized Calibration) are used.

20.7 Use of Lysimeters in India

- India has lysimeter stations in research centers like IARI (New Delhi), PAU (Ludhiana), and ICRISAT (Hyderabad).
- Help in developing crop coefficients for different agro-climatic zones.

20.8 Crop Coefficients and Reference ET (ET_0)

- FAO Penman-Monteith is the most accepted method to compute reference ET.
- Crop coefficient K_c values vary with crop type and growth stage.

$$ET_c = K_c \cdot ET_0$$
